PUBLICATIONS

1. " Transition from NASA Space Communication Systems to Commercial Communication Products", Proceeding of Dual-Use Space Technology Transfer Conference, NASA JSC, Houston, February 1994.

2. " A Novel Approach to Model the Viterbi Decoded Error Sequence", Proceeding of Globecom '93, Houston, November 1993.

3. " Acquisition of the QPSK Demodulator in the Presence of Interference", Proceeding of MILCOM '90, Monterrey, October 1990.

4." Self Interference Impact of Operating Data Relay Satellite in Close Proximity to Each Other"' Proceedings of International Conference on Communication Systems ICCS '88, Singapore, March 1988.

5. " Application of Expert System in CLASS", Proceedings of International Communication Conference ICC '88, Philadelphia, June 1988.

6. " Network synchronization ", with W.C. Lindsey, W.C. Hagmann, and K. Dessouky, Proceedings of IEEE, October 1985.

7. " Network Synchronization Techniques: An Overview ", with W.C. Lindsey and W.C. Hagmann, NTZ Archive, July 1982.

8. " A Time Synchronization and Ranging System ", with F. Davarian, Proceedings of International Communication Conference ICC '82, Philadelphia, June 1982.

9. " Phase Noise Effect on Synchronous Network Performance ", with W.C. Lindsey and W.C. Hagmann, Proceedings National Telecommunication Conference NTC '81, New Orleans, December 1981.

10. " Synchronization of Digital Communication Networks ", Ph.D. Dissertation, University of California, Los Angeles, June 1981.

11. " Synchronization Techniques for Mobile User Satellite Systems ", with W.C. Hagmann and W.C. Lindsey, International Communication Conference ICC '81, Denver, June 1981.

12. " Time and Frequency Transfer in a Data Communication Network ", with W.C. Lindsey and W.C. Hagmann, Proceedings International Symposium on Information Theory, Santa Monica, February 1981.

13. " Dissemination of Time in a Digital Communication Network ", with W.C. Lindsey, Proceedings of National Radio Science Meeting, Boulder, January 1981.

AFFIDAVIT OF MARK A. STURZA

I, Mark A. Sturza, do depose and state as follows:

1. I am an electrical engineer specializing in Communication Systems Engineering, retained by Teledesic Corporation. Additional information concerning my engineering background and activities is shown in Attachment A hereto.

2. I prepared with Farzad Ghazvinian the Engineering Exhibit which is attached to the foregoing Reply Comments of Teledesic Corporation in the matter of Amendment of Parts 2 and 15 of the Commission's Rules to Permit Use of Radio Frequencies Above 40 GHz for New Radio Applications. Except for those factual matters of which official notice may be taken or which are matters of public record, the statements made in that engineering exhibit are true, complete and correct to my personal knowledge.

Date: 28 February 1995

Mark A. Sturza

MARK A. STURZA

SWORN to before me, the undersigned Notary Public, this 28 day of ~~March~~ February, 1995.

LLD

Laura L. Dunning

Notary Public in and for the District of Columbia

Laura L. Dunning
Notary Public, District of Columbia
My Commission Expires March 31, 1995

The following is a supplement to the affidavit of Mark A. Sturza, 16161 Ventura Blvd. #815, Encino, CA 91436, Telephone Number (818) 907-1302.

I, Mark A. Sturza, received my BS in Applied Mathematics from the California Institute of Technology, (Pasadena, California), in 1977, my MSEE from the University of Southern California, (Los Angeles, California) in 1979, and my MBA from Pepperdine University, (Malibu, California) in 1985.

I have over 17 years of experience in the field of communications systems engineering.

From 1989 to the present I have been an independent consultant engaged in the design, development, and analysis of communications systems. My areas of specialization include: satellite communication systems, microwave radio systems, radio navigation systems, spread spectrum systems, and international and domestic regulatory support.

I was previously employed by Litton Aero Products as Director of Systems Engineering and as Director of GPS Development, by Magnavox Advanced Products and Systems Company as a Senior Engineer, and by Teledyne Systems Company as a Research Scientist.

I am a member of the Institute of Electrical and Electronics Engineers, a member of the Institute of Navigation, and a member of the American Institute of Aeronautics and Astronautics.

I have authored numerous technical papers in the areas of communications systems and of navigation systems that have been published in conference proceedings or technical journals.

I hold six U.S. patents and have several patents pending.

I have been an instructor at numerous short courses in the areas of communications systems and of radionavigation.

I have been an instructor in the School of Engineering at California State University, Northridge.

MARK ALAN STURZA

3C Systems Company
16161 Ventura Blvd. #815
Encino, CA 91436

(818) 907-1302
Fax (818) 907-1357

1989 to Present

<u>3C SYSTEMS COMPANY</u>
Encino, California

<u>**President**</u>

Founded 3C Systems as a consulting company providing expertise in the design, development, analysis, and regulation of communications systems. Areas of specialization include: satellite communication systems, microwave radio systems, radio navigation systems, spread spectrum systems, and international and domestic regulatory support. Assignments have included:

<u>Director of Communications Systems for Teledesic Corporation.</u>
Member of the original Teledesic (Calling Communications) technical team. Developed the communications systems architecture for this low-Earth orbit (LEO) Ka-band satellite communications system including radio frequency plan, multiple access techniques, and link budgets. Prepared the technical sections of the Teledesic FCC application and amendments. Provided technical inputs for various domestic and international regulatory filings.

Member of the Teledesic management team. Contributed to the design of the Teledesic organization. Helped formulate Teledesic regulatory strategy. Responsible for all Teledesic communications systems design and analysis, and regulatory support engineering activities. Managed support contractors and consultants to refine the communications systems design and to prepare technical analysis of regulatory issues. Surveyed potential Teledesic suppliers.

<u>Communications Systems Engineer for LEO One Satellite System.</u>
Developed the communications system architecture for this "Little-LEO" VHF/UHF store-and-forward satellite system including radio frequency plan, multiple access techniques, and link budgets. Designed satellite constellation orbits. Developed network protocols. Identified satellite and user terminal requirements.

Prepared technical sections of FCC application and amendments. Provided technical inputs for various domestic and international regulatory filings. Managed support contractors and consultants to develop constellation analysis software program, to analyze constellation performance, and to refine the communications systems design. Evaluated potential satellite vendors.

Principle Investigator for 4 DOD SBIR Phase I Contracts.
Prepared proposals for and was awarded four DOD SBIR Phase I contracts. Performed trade studies and prepared final reports for the following topics:
- QPSK and MPSK Transmission and Receiving Equipment
- RPV Range Surveillance and Radio Relay Via Satellite
- Miniature GPS Digital Translator Development
- ECM Resistant GPS Receiver

Radionavigation Systems
- Redesigned the RF front end of a high performance GPS receiver to reduce cost, size, weight, and power consumption.
- Developed an ultra-low production cost GPS receiver module.
- Developed a post-test GPS software receiver program.
- Performed trade studies for a L-Band digitizing GPS receiver.
- Developed a miniaturized L-Band to S-Band GPS Translator and associated S-Band to L-Band receiver.
- Designed receiver tracking loops for a very high dynamic (50 g, 50 g/sec) application.
- Performed a study analyzing direct sequence spread spectrum receiver implementation loss sources.
- Developed several miniaturized low-power S-Band, L-Band, and VHF frequency synthesizers.
- Developed a differential GPS navigation filter with autonomous fault detection.
- Conducted a study of the receiver autonomous integrity monitoring (RAIM) performance of an integrated GPS/GLONASS receiver.

Miscellaneous Communications Systems
- Performed a trade study comparing narrow band and spread spectrum wireless security systems.
- Performed a feasibility study of wireless cable systems (LMDS, MVDS, and MMDS) using digital modulation techniques.
- Prepared requirements flowdown for a K-band low noise amplifier/downconverter, a L/C-band switchable upconverter, and a SHF/70 MHz down converter.

Inertial Navigation Systems
- Developed algorithms for skewed axis inertial navigation system (INS) fault detection and isolation (FDI).
- Performed a study of the long duration performance of aircraft inertial navigation systems.

Miscellaneous
- Served as a Member of the Board of Directors of a small high-tech corporation.
- Provided technical expert support to several patent attorneys.
- Conducted due diligence investigations of several high technology companies.

1987 to 1989

LITTON GUIDANCE & CONTROL SYSTEMS
Woodland Hills, California

Member Technical Staff, Advanced Systems Engineering

Transferred to Guidance & Control Systems Division to pursue interest in fiber optic products. Engineering proposal manager for successful All Optical Towed Array (AOTA) proposal. Principal investigator for Fiber Optic Acoustic Detection System (FOADS) program. Developed real-time 10 Hz to 20 KHz FFT spectrum analyzer with one-third-octave outputs based on TMS 320C30 and 386 PC. Designed digital signal processing techniques for fiber optic hydrophone demodulation. Engineering proposal manager for various fiber optic gyro (FOG) proposals. Investigated signal processing techniques for FOGs.

Principal investigator for Integrated GPS/Inertial System R&D program. Engineering manager for GPS Guidance Package (GGP) study. Provided consulting expertise to all Guidance & Control Systems GPS/Inertial programs.

1981 to 1987

LITTON AERO PRODUCTS
Moorpark, California

Director, Systems Engineering

Promoted when new Engineering VP was appointed. Responsible for all systems engineering activities across all product lines (INS, IRS, AHRS, Omega, GPS, and advanced systems). Reorganized directorate into four departments (analysis, design, integration, and test) each managed by an Engineering Manager. Increased directorate from 35 engineers to 55 engineers to support work load. Reduced back to 35 engineers eighteen months later when company management decided to sharply curtail engineering activity. Established a summer intern program for engineering students.

Managed system design of fault-tolerant fiber optic gyro IRS system, development of improved strapdown system calibration, investigation of RLG instrument block vibration, development of PC based system test equipment, and conceptual design of new products. Developed policies and procedures to improve systems engineering effectiveness and efficiency.

1981 to 1985

Director, GPS Development
Project Engineer, New Product Development
Member Technical Staff, New Product Development

Recruited by Litton to lead their GPS development effort. Starting form scratch with a team of 3 engineers, developed working brassboard during the 1st year. Conducted successful flight tests by end of 2nd year. Completed production prototypes within 3 and 1/2 years. Interfaced with Manufacturing for limited production run of 25 LTN-700

GPS Navigation Sets. Developed system architectures for 2nd and 3rd generation products (LTN-710 and μNAV). Developed codeless L2 signal processing technique incorporated in Western Atlas Aero Service's GPS survey set (MINI-MAC). Developed single channel GPS signal generator for receiver testing. Developed digital Omega receiver.

Managed project budget of $1 to $2 million per year. Directly responsible for GPS systems engineering and RF design groups (increased staff from 2 engineers to 7 engineers). Managed CMOS gate array and custom GaAs developments. Established state-of-the-art RF development lab for work from 10 MHz to 2 GHz.

1979 to 1981

MAGNAVOX ADVANCED PRODUCTS AND SYSTEMS COMPANY
Torrance, California

Senior Engineer, Communication Systems Engineering

Recruited by Magnavox to join their Phase II GPS development team. Designed the set moding for the five, two, and one channel GPS Phase II User Equipment (UE) sets. Performed various system engineering tasks for GPS Phase II UE sets.

1979

TELEDYNE SYSTEMS COMPANY
Northridge, California

Research Scientist, Engineering

Returned to Teledyne after receiving MSEE from USC. Designed a simplified test procedure for the DRIRU-II gyro that significantly reduced test time. Conducted processor requirements study for Missile Accuracy Evaluator (MAE) GPS receiver.

1978 to 1979

Consultant

Worked my way through USC MSEE program by consulting for Teledyne. Conducted performance trade-off studies for GPS Phase IIA program. Performed hardware/software integration of Tactical GPS Guidance (TGPSG) receiver. Designed and implemented a GPS satellite simulator using off-the-shelf subsystems.

1977 to 1978

TELEDYNE SYSTEMS COMPANY
Northridge, California

Member Technical Staff, Advanced Systems Engineering

Joined Teledyne after completing BS at Caltech. Designed and implemented an improved graphics capability for St. Marys Loran-C navigation system. Developed and analyzed algorithms for Tactical GPS Guidance (TGPSG) receiver.

Summers 1974, 1975, 1976

TELEDYNE SYSTEMS COMPANY
Northridge, California

Simulated CH-46 Doppler-Omega navigation system. Developed a GPS receiver simulation. Analyzed the effect of sequencing on tracking loop stability. Analyzed various navigation system configurations.

EDUCATION:

BS, California Institute of Technology, 1977
MSEE, University of Southern California, 1979
MBA, Pepperdine University, 1985

PERSONAL:

Born January 17, 1957
Valid Passport
Secret Clearance

PROFESSIONAL AFFILIATIONS

IEEE, ION, AIAA

PUBLICATIONS

"St. Marys River Loran-C Precision Guidance Systems Improvements", NTIS AD-A062160, September 1978, with E. Dietrich and J. Holdsworth.

"GPS Navigation Using Three Satellites and a Precise Clock" Navigation: Journal of the Institute of Navigation, Volume 30, No. 2, 1983.

"A GPS Navigation Set for Commercial Aviation Applications", SAE 1983, Aerospace Congress & Exposition, October 1983.

"Digital Signal Processing Techniques for GPS Receivers", National Telesystems Conference, November 1983.

"Commercial Aviation GPS Navigation Set Architecture", ION National Technical Meeting, January 1984.

"GPS/AHRS: A Synergistic Mix", NAECON, May 1984, with A. Brown and J. Kemp.

"Static Point Positioning using the Global Positioning System", 35th Congress of the IAF, Switzerland, October 1984, with A. Brown.

"Static Point Positioning with an L1, C/A Code GPS Receiver", First International Symposium on Precise Positioning with the Global Positioning System, April 1985, with A. Brown.

"Commercial Aviation GPS Navigation Set Flight Test Results", Institute of Navigation National Technical Meeting, June 1985, with A. Brown.

"MINI-MAC --- A New Generation of Dual-Band Surveyor", Fourth International Geodesic Symposium on Satellite Positioning, April 1986, with A. Brown, J. Ladd, and R. Welshe.

"Design of Differential GPS Receivers for Marine Navigation", RTCM Annual Assembly Meeting, May 1986, with A. Brown.

"GPS Ground Proximity Warning System", ION National Technical Meeting, January 1987.

"Skewed Axis Inertial Sensor Geometry for Optimal Performance", AIAA/IEEE Digital Avionics Systems Conference, October 1988.

"Embedded GPS Solves the Installation Nightmare", PLANS '88, November 1988, with C. Richards.

"Navigation System Integrity Monitoring Using Redundant Measurements", NAVIGATION: Journal of The Institute of Navigation, Volume 35, No. 4, 1988-89.

"Integrated GPS/GLONASS for Reliable Receiver Autonomous Integrity Monitoring (RAIM)", Institute of Navigation Annual Meeting, June 1990, with A. Brown.

"The Effect of Geometry on Integrity Monitoring Performance", Institute of Navigation Annual Meeting, June 1990, with A. Brown.

"Fault Detection and Isolation (FDI) Techniques for Guidance & Control", NATO AGARDgraph GCP/AG.314 Analysis, Design and Synthesis Methods for Guidance & Control; June 1990.

"Advantages of Digital Translators for GPS TSPI Applications", ION Satellite Division 3rd International Technical Meeting, September 1990, with A. Brown.

"Fault Tolerant GPS/Strapdown Inertial System Design", ION Satellite Division 3rd International Technical Meeting, September 1990, with F. DeAngelis, D. Lukaszewski, and A. Brown.

"Comparison of Fixed and Variable Threshold RAIM Algorithms", ION Satellite Division 3rd International Technical Meeting, September 1990, with A. Brown.

"Digital Translator Design Trades", ION Satellite Division 5th International Technical Meeting, September 1992, with A. Brown.

"The Teledesic Satellite System", National Telesystems Conference, May 1994.

"The Teledesic Satellite System: Overview and Design Trades", Third Annual WIRELESS Symposium, February 1995.

"Architecture of the Teledesic Satellite System", International Mobile Satellite Conference, June 1995.

PATENTS

4,584,652	Apparatus and Method for Determining In-phase and Quardrature-phase Components
4,642,647	Signal Generator for Radio Navigation System
4,706,286	Method and Circuit for Extraction of Doppler Information from a Pseudo-Noise Modulated Carrier
4,849,961	Fast Sequencing Demodulation Method and Apparatus
4,862,178	Digital System for Codeless Phase Measurement
5,225,842	Vehicle Tracking System Employing Global Positioning System (GPS) Satellites
	Additional Patents Pending

UCLA SHORT COURSE INSTRUCTOR

Integrated Communications, Precision Positioning Determination and Navigation, and Identification Systems; Principles, Technology, & Operational Aspects — March 1985, March 1986.

NAVSTAR Global Positioning System (GPS): Operation, Implementation, and Applications — June 1985, June 1986, December 1986, June 1987, December 1987, June 1988, December 1988.

CSUN INSTRUCTOR

EE 351, Linear Systems II — Discrete Linear Systems, Fall 1988.

UCCE SHORT COURSE INSTRUCTOR

NAVSTAR/GPS: Operation, Implementation, and Applications — October 1990, November 1990, May 1991, November 1991.

The following is a supplement to the affidavit of Mark A. Sturza, 16161 Ventura Blvd. #815, Encino, CA 91436, Telephone Number (818) 907-1302.

I, Mark A. Sturza, received my BS in Applied Mathematics from the California Institute of Technology, (Pasadena, California), in 1977, my MSEE from the University of Southern California, (Los Angeles, California) in 1979, and my MBA from Pepperdine University, (Malibu, California) in 1985.

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I was previously employed by Litton Aero Products as Director of Systems Engineering and as Director of GPS Development, by Magnavox Advanced Products and Systems Company as a Senior Engineer, and by Teledyne Systems Company as a Research Scientist.

I am a member of the Institute of Electrical and Electronics Engineers, a member of the Institute of Navigation, and a member of the American Institute of Aeronautics and Astronautics.

I have authored numerous technical papers in the areas of communications systems and of navigation systems that have been published in conference proceedings or technical journals.

I hold six U.S. patents and have several patents pending.

I have been an instructor at numerous short courses in the areas of communications systems and of radionavigation.

I have been an instructor in the School of Engineering at California State University, Northridge.

APPENDIX B

RADIOCOMMUNICATIONS
AGENCY

MULTIPOINT VIDEO

DISTRIBUTION SYSTEMS

REPORT OF THE 40 GHZ MVDS WORKING GROUP

Radiocommuncations Agency
November 1993

MULTIPOINT VIDEO

DISTRIBUTION SYSTEMS

REPORT OF THE 40 GHZ MVDS WORKING GROUP

Contents

Radiocommunications Agency
November 1993

1. INTRODUCTION

1.1. This report seeks to assist those interested in the establishment of multipoint video distribution systems (MVDS). It summarises much of what is presently known about the local delivery of television services using these new wireless techniques - drawing on the deliberations of an ad hoc group convened by the Radiocommunications Agency in November 1990.

1.2. The report complements the technical standard for licensing analogue MVDS transmitters which has also been prepared by the ad hoc group. That specification (number MPT 1550) lays down all the requirements that are imposed on transmission equipment. It should be noted that the specification does not address the requirements of the European Community (EC) Electro Magnetic Compatibility (EMC) Directive. (Any enquiries on EMC issues should be made, in the first instance to the Radiocommunications Agency). The specification, although referring to analogue transmitters, does not preclude the use of digital techniques but these will be subject to further consideration by the Radiocommunications Agency. It is not intended that this report should impose any further obligations on operators or manufacturers.

2. SUMMARY

2.1. MVDS is a means of delivering multichannel television to a particular locality, and may be used (in conjunction with or as an alternative to cable delivery) for Local Delivery Services (LDS) within the meaning of the Broadcasting Act 1990.

2.2. A single transmitter using the 40 GHz band that has been allocated to MVDS might be able to serve an area of 12.5km^2, and larger areas could be served by using a small network of transmitters. Receiver antennas would however need to have direct line of sight to the transmitter to ensure satisfactory reception, thus requiring careful siting of the transmitters. The spectrum available could typically provide for 32 channels within a locality. Much of the equipment required within the home could be the same as that needed for existing direct-to-home (DTH) satellite services, but equipment specifically related to the 40 GHz transmissions is still being developed.

2.3. A typical MVDS operation will comprise three basic elements:

a. the main transmission site, including receiving antennas for the services being provided off-air (terrestrial UHF television services, a variety of satellite services) and means for inputting other programming, for example from videos, and (possibly) very localised services, together with means for encrypting those services which are to be provided in this form;

b. subsidiary transmission sites, relaying the signals received from the main transmission site, (possibly requiring re-encryption of the signals);

c. domestic reception sites (normally individual houses/flats), having an MVDS receiving antenna, tuning and decoding equipment, and a television set.

There may also be a fourth element: master antenna reception sites, which receive signals and redistribute them to houses/flats which have no direct line of sight to a transmitter.

3. BACKGROUND

3.1. **The ad-hoc 40 GHz MVDS Working Group was set up by the Radiocommunications Agency in November 1990. The aim of the Group was to assist the DTI, the Independent Television Commission (ITC), equipment manufacturers and potential users in formulating broad plans for the use of MVDS for the local delivery of television services. The Group's membership included the ITC, BBC, the Cable Television Association, National Transcommunications Ltd, BREMA, EEA (and a number of its member companies). A list of Members and others who attended the group's meetings is contained in Appendix A.**

3.2. **The Group addressed issues such as the uses of MVDS, technical parameters, equipment and specifications etc with a view to producing recommendations on overall plans for MVDS.**

3.3. The framework against which the Group's work was set included:

- the report to the DTI in early 1988 by Touche Ross International on the Potential for MVDS in the UK;
- the statement in August 1989 that the DTI would make available the 40 GHz band (ie 40.5 to 42.5 GHz) for MVDS; and
- the provisions of the Broadcasting Act 1990 which made the ITC responsible for Local Delivery Services (LDS) which provided television services to more than 1000 homes (whether by cable or MVDS or a combination of both).

3.4. The ITC was open to enquiries about licences for LDS from 1 January 1991. The Commission might also advertise licences for extensions of existing systems, new SMATV systems or green field sites. The Commission announced however that new local delivery licences would not for the time being be advertised in areas which were already the subject of a cable franchise.

3.5. The ITC was also open to applications for conversion to local delivery licences of the first 32 cable franchises. Such applications had to be made before the end of June 1991. In the event 9 such applications were received. The principal advantages of such conversion would be the possibility of delivery by MVDS and the dropping of the "must carry" rule.

4. THE WORK OF THE GROUP

4.1. The Group held 13 meetings in the period November 1990 to January 1993, and reviewed the issues affecting the delivery of television services by MVDS.

4.2. The Group has produced a performance specification to be used in the Wireless Telegraphy licensing of MVDS transmitters (MPT 1550). A lot of other useful information was also fed into the Group, and this summary report of the Group's work aims (for the benefit of potential users of MVDS, potential manufacturers of equipment, and other interested parties, like the ITC and the Radiocommunications Agency) to draw together this information.

4.3. The Group did not address the possibility of using frequencies outside the 40 GHz band. However it should be noted that in October 1991 the Department of Trade and Industry announced that it was prepared to sanction practical tests to determine whether MVDS could operate in the 11.7 to 12.1 GHz sub-band without interfering with the existing users of the band. Such tests have not yet been carried out. In the event of successful tests being conducted, it is possible that additional provision could be made for MVDS within this band, though restrictions on power levels would be likely to ensure satisfactory sharing of the band, and the number of channels available would be rather less than available in the 40 GHz band.

5. CONTENT OF REPORT

5.1. This report covers:-

a. possible uses of MVDS which are being catered for;

b. possible coverage obtainable with MVDS, including propagation characteristics;

c. frequency planning factors;

d. likely receiver characteristics that would constrain transmitters;

e. basic transmitter characteristics;

f. possible equipment costs.

6. POSSIBLE USES OF MVDS

6.1. MVDS is a means of providing local delivery of television services in accordance with Part II of the Broadcasting Act 1990. Its use is therefore dependent on the award of a local delivery licence by the ITC under the procedures laid down in that Act. The way in which applications are to be made to the ITC is set out in a note published by the Commission (reproduced as Appendix B). The ITC has indicated that for the time being no such licences will be advertised in areas which are currently the subject of cable franchises.

6.2. MVDS is therefore usable only in the new areas which will be advertised for local delivery licences, or in any of the first 32 cable franchise areas where the operators exercised their option to convert to a local delivery licence.

6.3. In both cases, MVDS could be used within a licence area in conjunction with cable delivery, or possibly as the sole means of delivering television services. It has also been suggested that MVDS might be used as a means of delivering services to parts of a franchise area for a temporary period in advance of the full cabling of the area - thereby delivering programmes, and obtaining revenue from viewers, in advance of full cabling.

6.4. The choice between delivery by cable or MVDS will need to be made by the licensee in the light of local circumstances. Discussions with existing cable franchise holders suggest that cable is seen as offering long term benefits that cannot be matched by MVDS (for example, two-way telecommunications capability, very high population coverage, potential use of trunk optical fibre distribution networks for additional alternative telecommunications use).

6.5. The consensus within the Group was that MVDS would need to deliver at least 25-30 channels if it were to be seen as a real alternative to cable. MVDS would also need to be competitive with direct-to-home satellite services both in terms of the numbers of channels that could be delivered and in the price of domestic receivers. An outline comparison of the costs of cable and MVDS systems is contained in Paragraph 11.5.

6.6. Since much of urban Britain is already subject to cable franchises, the remaining towns to be served are generally small. One MVDS transmitter is likely to be able to serve an area of 12.5km^2, and may thus just be sufficient to cover typical small/medium towns, many of which are unlikely to be cabled this century. On the assumption that there are approximately 490 homes per km^2 in this type of urban environment, and the number of people per home is about 3, the population that could be covered by a transmitter which could be seen by 70% of the homes would be around 12900.

6.7. One of the big advantages of MVDS is the flexibility of its programme carrying capabilities. Since the transmission path is transparent to the format of the video signal, transmission standards such as PAL I, D2-MAC and HD-MAC could be carried on the system. However the number of channels is a function of the baseband and modulation parameters.

6.8. Some interest has been shown in having interactive MVDS systems. A narrow-band speech channel, back to the single point distribution, might be feasible, but this has not been included in the general plan drawn up within the Group.

6.9. Since the original fifth terrestrial television network proposal is only likely to cover up to 70% of the UK population, it has been suggested that MVDS could be used to supplement coverage in the remaining areas. This however would need to be done in conformity with the provisions of the Broadcasting Act.

7. PROPAGATION AT 40 GHZ

7.1. The 40 GHz band has been chosen as the primary band for analogue MVDS since it is only in this band that around 30 channels can be provided - discussions in the Group suggesting that users would require at least 25-30 channels to offer a competitive local delivery system (though in some limited cases a smaller number of channels might be acceptable for a limited period, or for specific applications).

7.2. The 40 GHz band has moreover been recommended by the CEPT as the primary band for MVDS in Europe - thus enhancing the chances of a wide range of equipment being developed and manufactured. (The text of the recommendation is contained in Appendix C).

7.3. Broadcasting using microwave frequencies does however differ from conventional terrestrial broadcasting in that the maximum size of the area served by each transmitter is rather less than that served by a main UHF transmitter. A typical small town could possibly be served by a single transmitter, though for the reasons given below several transmitters may be needed in practice. The service provided can however be made specific to the particular area.

7.4. MVDS receiver antennas will need to have direct line of sight to the transmitter. Reception would be affected by any obstacle in the path of the signal, including buildings and trees. Within the circumference of an area where the strength of the transmitted signal should be sufficient for adequate reception, there may be a number of dwellings which have no direct line of sight to the transmitter, and therefore other means of delivery to some dwellings might be necessary if it is desired to ensure complete coverage of a particular area. Studies suggest that for typical areas about 60 to 70% of homes should be able to receive a signal directly. This figure could be increased using cable distribution. For master antenna television installations the receive antenna heights could be increased to ensure good line of site to the transmitter.

7.5. At 40 GHz the service area of an MVDS transmitter is limited by the horizon, as well as by any other obstacles between the transmitter and receiver, including trees and rainfall. Presently available technology only permits transmission over a few kilometres. Technology however is evolving rapidly and new devices (for example, monolithic devices using high electron mobility transistors (HEMT)) are now on the verge of becoming available which will improve the performance of receivers, and later transmitters.

7.6. The limit of a service area will be determined by the received signal strength under conditions of heavy rain. Rainfall varies from year to year, but the statistics on which propagation prediction is based are constant. As the threshold for rainfall rate (and thus attenuation) is increased, the proportion of the time that it is exceeded drops rapidly. The Working Group assumed that the threshold adopted in service planning would be similar to that for DBS direct-to-home services, ie. for the received signal to exceed 12 dB C/N (picture grade 4) for 99% of the worst month (99.7% of the year) at the edge of the service area.

7.7 The rainfall rate exceeded for 1% of the worst month (WM) is 7 mm/h, while that for 0.1% of the worst month is 20 mm/h (CCIR rain zone G). At these rainfall rates, rain attenuations are estimated to be 2.1 and 5.7 dB/km, respectively. An assessment of the approximate average annual number of fades caused by continuous rain in excess of these rain rates has been obtained from measurements of rain rate durations in southern England, shown in the following table.

Approximate number of fades per year

Duration (secs)	7 mm/h	20 mm/h
30	300	50
60	150	20
120	100	8
240	40	2

(These figures suggest that for 1% WM (0.3%t) total faded time, where picture quality is less than CCIR Grade 4, is 11 hours per year. For 0.1% WM (0.03%t) it is 1.15 hours/year. However, the ability of receivers to maintain a locked picture, albeit at lower picture grades, below a C/N ratio of 12dB mitigate against the effects of high attenuation at 40 GHz caused by rainfall).

7.8. In addition to attenuating the wanted signal, rainfall can also transfer signal power into the orthogonal polarization, which could have an impact on the use of polarization diversity to improve spectrum utilization. There are very few measurements of rain-induced cross-polar discrimination (XPD) at frequencies near 40 GHz, but an assessment from current theoretical models of XPD suggests that at a rain rate of 25 mm/h, the rain-induced cross-polar discrimination would be of the order of 25 dB for a 5 km path, and is some 7 - 10 dB better than the worst-case (off bore-sight) values quoted for antenna XPD. Rain-induced XPD is therefore not expected to be a problem.

7.9. A theoretical assessment of clear-air multipath effects has indicated that, for typical paths of up to 5 km length, multipath fading will generally be less than 3 dB, while the maximum delay on such paths would be about 9 ps at 40 GHz.

7.10. Propagation experiments are still being carried out to examine the characteristics of transmissions at 40 GHz. In particular, there is little information available at present on the likelihood of anomalous propagation caused by the effects of ducting conditions. Work is in progress to investigate these effects, both inland and in coastal areas, where the evaporation duct may be prevalent. The results of these experiments will be published as soon as they are available, and will assist in determining optimum frequency re-use distances.

8. FREQUENCY PLANNING FACTORS

8.1. At present around 65% of the population of Great Britain live in areas which are subject to cable franchises. This covers most of the urban Britain. There are around 20 large towns (with more than 20,000 homes) which are not covered by a franchise - these areas are listed in Appendix D.

8.2 It is assumed that not all new local delivery licence areas would wish to use MVDS, and therefore there seems no reason at present to assume the need for a detailed national frequency plan to provide for MVDS throughout the country. The adoption of a 32 channel planning criterion as the guideline would provide franchisees with considerable scope and flexibility, whilst maintaining a sensible basis for the future expansion of MVDS. In the medium term frequency planning would best proceed on an ad hoc basis. Each "technical plan" presented by an LDO applicant would need to be assessed on an individual basis for coverage and interference potential. It would be expected that the plan will make sensible use of terrain, directional aerials etc. so as to minimise interference to other existing or potential MVDS operators.

8.3. To provide a satisfactory number of channels whilst maintaining maximum flexibility for allocations to small town areas in future, it is proposed that a 32 channel plan be adopted for MVDS as detailed in Appendix E. This plan will provide four channel groups within the 2 GHz band using both vertical and horizontally polarised transmissions. The plan assumes channel standards similar to those used for current direct-to-home (DTH) satellite services, thereby allowing the use of DTH receiver technology. It is recognised that the use of other channelling standards will impact the number of channels, but is not necessarily precluded.

8.4 It is, however, necessary to use extended frequency range indoor units capable of tuning from 950 - 2000 MHz rather than the normal current frequency range of 950 - 1750 MHz, if all 32 channels are to be used. The design of the receiver and low noise block converter will have a bearing on any taboo channel relationships, and the use of either a Gunn oscillator or Travelling Wave Tube amplifier approach for the transmission systems may have a significant impact on the potential number of unusable channels.

8.5. In order to protect the Radio Astronomy Service from interference in the band 42.5 GHz to 43.5 GHz, the transmitter spurious limits have been set at -80 dBW in this frequency range. This limit, which can be achieved by manufacturers, has the effect of reducing the co-ordination distance required from 40 km to under 1 km.

8.6. It is assumed that frequency modulation will be used.

8.7. Sectoral horns should be employed where possible to make the most efficient use of the available spectrum - indeed the use of omni-directional antennas, except in the most isolated areas, may limit the re-use of the spectrum available. As already noted, the receiver antenna needs to be at a height that provides a clear line of sight to the transmitter.

8.8. If the use of a travelling wave tube broad band amplifier approach is possible, multiplexing at the transmission site may be possible to avoid separate antennas for each channel.

8.9. It is desirable that the local oscillator frequencies for the MVDS receivers should be within the frequency band allocated for the service. This should help minimise interference problems that could occur to other services in adjacent frequency bands. It is suggested that the nominal local oscillator frequency for receivers tuning the lower frequency channel groups should be 42.44925 GHz, and the corresponding frequency for the two upper channels groups should be 40.55 GHz. This gives rise to the signal/first IF given in the table in paragraph 9.5.j. It will be noted that the frequency of the local oscillator when tuning low channel groups is within the MVDS channels 126-128, and conversely within channels 1-3 when receiving the upper channel groups. However since the geographic siting of other MVDS transmitters within a given franchise will be selected by the Local Delivery Licensee (if within the franchise area) the potential problem of in-channel interference can probably be minimised. It should be noted that at the majority of domestic locations the bearings of neighbouring MVDS transmitters will differ, ie some antenna discrimination should be obtained either by cross polarisation, or by azimuthal discrimination or a combination of both. The level of local oscillator power radiated at the domestic antenna should also be at a level below -30dBm.

8.10. Image response frequencies for MVDS receivers using local oscillator frequencies proposed above are between 43.4 and 44.4 GHz, and between 38.6 and 39.6 GHz. At present PCN fixed link services are becoming operational in the low image response band, and a number of very high power links are already in operation in the upper response channel. These services could therefore be potential sources of interference to any future MVDS services in the 40 Ghz band. However most PCN links will operate in a point to point mode, ie narrow beam aerials will be used and hence the probability of the PCN-transmitting and the MVDS-receiving aerial beams intersecting should be low. In addition, most (if not all) of the small number of satellite uplinks operating in the 44 GHz band are remotely sited in the countryside, and are therefore unlikely to be a major problem.

9 RECEIVER CHARACTERISTICS

9.1. It is assumed that the MVDS system should be compatible with existing domestic reception equipment. It is likely that reception and descrambling equipment will, like cable TV, be supplied by the service provider. However to keep costs down it will be important that such equipment does not have to be designed specifically for MVDS. This could be achieved by combining elements of cable TV and satellite reception equipment. One important factor is that most existing satellite receiver indoor units have a tuning range of only 800 MHz, whereas those likely to be needed for a full MVDS service need to tune over about 1000 MHz.

9.2. It will be essential, for MVDS to be viable, that the microwave front-end of the receiver can be made at low cost. Most currently available components use waveguide machined from solid: they are expensive and cannot readily be mass produced. However different transmission line structures have been developed for use in mass produced low cost millimetric components. So far these low cost units have not included a low noise amplifier (LNA) ahead of the mixer. However recent developments in HEMT technology allow monolithic amplifiers to be made with noise figures below 6.5 dB. It will also be possible to integrate the mixer on the same chip. If this were an image rejecting mixer then a filter to reject image noise (which could not be on the chip) would not be needed. Some filtering will probably still be needed to prevent interference from out-of-band signals, especially at the image frequency. This is particularly easy in finline using an etched metal insert.

9.3. Frequency stability is less important in the receiver local oscillator than in the transmitter because the offset can be corrected later in the receiver using automatic frequency control. However it must be kept below half the channel spacing otherwise the receiver will lock to the channel adjacent to the one wanted. Because of the low power needed by the mixer it is possible to use a HEMT as the active device in the oscillator and it will probably use a dielectric resonator for frequency control. The oscillator might operate at half the required frequency with either harmonic extraction or a separate frequency multiplier. It might also be possible to use a sub-harmonically pumped mixer. Phase noise performance is important (as it is in the transmitter) to achieve an adequate video signal to noise in the demodulated picture.

9.4. If there is no LNA, then the noise figure of the IF amplifier is important: 2 GHz broadband monolithic IF amplifiers are now readily available with noise figures below 3 dB.

9.5. For the purposes of planning, the following features and parameter values used for existing DTH services are assumed (though MVDS services are in no way obliged to follow these figures):

a. ASSUMED INPUT SIGNAL AT 1ST IF: the modulation characteristics are those of the current DTH services, for example, with the PAL system used for the video signal, any additional sound transmissions may conform to the Wegener "Panda I (1600 series)." In other cases the system might be D2MAC, as specified by the EBU: this is not reproduced here.

b. INPUT SIGNAL LEVEL (nominal Zin = 75 ohms):
   i. to reach the fm demodulation threshold -60 dBm;
   ii. to achieve a 48 dB weighted video signal to noise ratio -60 dBm;
   iii maximum for a single signal -15 dBm;
   iv. maximum for 16 equal level signals -30 dBm.

c. TUNING RANGE: in terms of nominal vision carrier frequencies:

current production:	0.95 to 1.75 GHz;
future production:	0.95 to 2.00 GHz

d. TUNING ERROR (accuracy of set top box and synthesizer): for the worst selected channel ±0.25 MHz.

e. NOMINAL VIDEO CARRIER FREQUENCY ERROR: due to received signal or outdoor unit at which AFC limit is reached: ±5 MHz. (NOTE: exceeding this frequency error may be such that ambiguity between the channels occurs).

f. REJECTION OF N±2 ODD OR EVEN CHANNELS: if an energy mask corresponding to that of the ASTRA transmission were used: 25 dB.

g. MODULATED UHF OUTPUT: CCIR System I PAL, selectable sound source where appropriate, level at least 1 mV into nominal 75 ohms. Frequency range channel 32 to 40.

h. BASE BAND VIDEO OUTPUT:
   i. Bandwidth 25Hz to 10.5MHz, within 2 dB to 8.4 MHz, within 3 dB 8.4 to 10.5 MHz.
   ii. Group delay error less than 25 ns.
   iii. Peak to peak level nominally 1V.
   iv. Nominal output impedance 75 ohms, return loss at least 20 dB.
   v. De-emphasis, selectable CCIR REC 405-1 or EBU MAC Tech. 3258.

i. BASEBAND SOUND OUTPUT: corresponds to European Standard EN50049 "PERITELEVISION".

j. LOCAL OSCILLATOR FREQUENCIES FOR MVDS RECEIVERS: as noted in paragraph 8.9, the local oscillator frequencies should preferably be within the frequency band allocated for the service, and it is proposed that the nominal local oscillator frequency for receivers tuning the lower frequency channel groups should be 42.44925 GHz, and the corresponding frequency for the two upper channels groups should be 40.55 GHz. The signal/first IF will be as follows:

Channel number	Local oscillator frequency (GHz)	Centre frequency of first IF (MHz)
1	42.44925	1914.25
63	42.44925	999.75
2	42.44925	1899.50
64	42.44925	985.00
65	40.550	985.00
127	40.550	1899.50
66	40.550	999.75
128	40.550	1914.25

9.6 The WARC 77 template will be used as a basis for the receiver antenna characteristics. The stability of the outdoor unit is likely to result in a maximum video carrier frequency tuning error of ±5 MHz.

10 BASIC TRANSMITTER CHARACTERISTICS

10.1. The transmitter antenna needs to be at a height sufficient to provide adequate penetration in the service area, but not high enough to cause significant interference to other service areas.

10.2. High transmitter powers are difficult to achieve above 40 GHz. This factor affects the choice of modulation for MVDS transmissions. FM transmissions (using DBS modulation parameters) require 24 dB lower carrier-to-noise ratio than AM/VSB for the same picture noise, and do not need the same linear amplifier as required for AM/VSB. As a result AM/VSB is not currently feasible. FM needs more than twice the spectrum of a comparable system, however, using AM/VSB.

10.3. The most readily available source of RF power at millimetric frequencies is the free running Gunn Oscillator. These can readily be obtained with output powers in the range of +20 to +23 dBm. It has the advantage that FM can be generated easily using a varactor diode in the oscillator cavity.

10.4. It would be possible to develop Travelling Wave Tube Amplifiers at these frequencies with powers approaching +50 dBm, but only at an expense which would require all the channels to pass through one amplifier. Howevere, with the amplifier output adjusted to reduce intermodulation products between channels to acceptable levels, the output power per channel would be similar to that of a Gunn Oscillator. Solid state amplifiers are now becoming available with comparable output powers to Gunn Oscillators, but not yet at comparable costs. At lower frequencies, the normal technique for transmitting several channels together would be to use separate power amplifiers followed by a resonant combiner. Each section of the combiner is a filter which must pass the whole of the wanted channel while rejecting adjacent channels. At 40 GHz it may just be possible to combine 20 channels into 2 GHz, but not into 1 GHz. A good